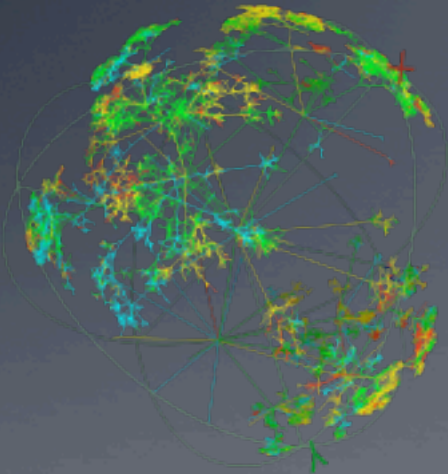


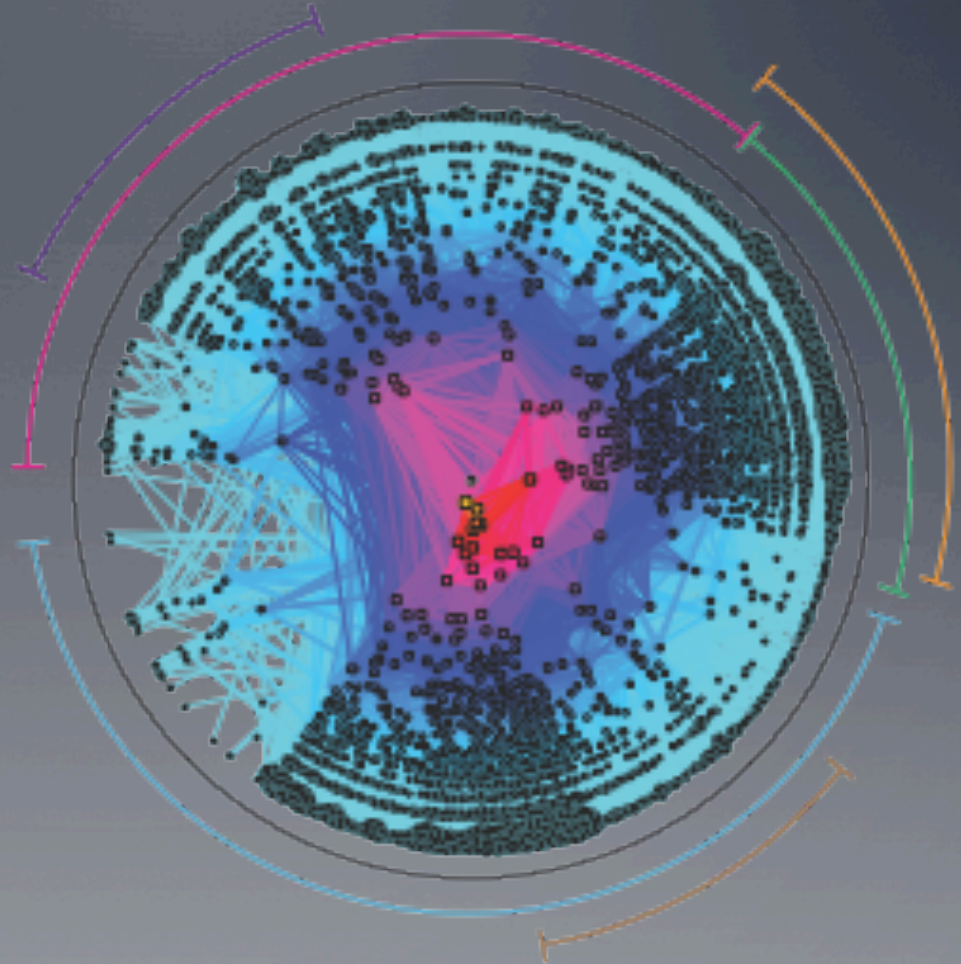
# Leveraging the Science and Technology of Internet Mapping for Homeland Security



Young Hyun, Ken Keys, Amogh Dhamdhere, Bradley Huffaker, Josh Polterock, Marina Fomenkov, Dima Krioukov, Matthew Luckie, and kc claffy

CAIDA/UCSD  
DHS S&T  
N66001-08-C-2029  
9 Oct 2012

<http://www.caida.org/>





# Addressing (Inter)national Security Needs

---

**Objective:** to improve DHS' situational awareness and understanding of the structure, dynamics and vulnerabilities of the physical and logical topologies of the global Internet.

**Solution:** to develop and implement new measurement and data collection technologies and infrastructure.

- *Macroscopic insight into the global Internet infrastructure...*



# Technical Approach

---

- Integrated six strategic Internet measurement and analysis capabilities:
  1. **New architecture** for continuous topology measurements (Archipelago, or “Ark”)
  2. **Topology analysis** techniques, e.g. IP alias resolution
  3. Dual **router**– and **AS**–level **graphs**
  4. **AS taxonomy** and **relationships**
  5. **Geolocation** of **IP** resources
  6. Graph **visualization**

<http://www.caida.org/funding/cybersecurity/>



# Technical Transfer Approach

- Integrated strategic measurement & analysis capabilities:
  1. **Ark** Measurement **platform**: software, data, access
  2. **Topology analysis**: software, data kits, papers
  3. Dual **router**– and **AS**–level **graphs**: software, viz
  4. **AS taxonomy** and **relationships**: published algorithms, interactive web service (**AS Rank**)
  5. **Geolocation** of **IP** resources: comparison report
  6. Graph **visualization**: part of AS Rank web service

[all software GPL or UCSD license (no patents); UCSD supports commercial license.]



# Benefits to DHS S&T

- Improve critical national capabilities:
  - **situational awareness** for homeland cybersecurity purposes
  - Internet **measurement**, **analysis**, and **inference** techniques
  - topology mapping: **annotated** AS+router **graphs**
  - **geolocation** technology **assessment**
- Address network science crisis:
  - **flexibility** in **measurement** methods
  - spend **less time** on **non-research** activities
  - **rapid prototyping**, high-level programming model



# Archipelago (Ark)



- **Launched** 12 Sept 2007 w/ 8 monitors
- **60** active **IPv4** probers (July 2012)
  - 17 in US
- **28** active **IPv6** probers
- **31 countries**
- Support for **meta-data management**
- **Collaborators run** vetted measurements on security-hardened platform
- **Publish statistics** and **analysis** of views from individual monitors

## Ark monitor locations



<http://www.caida.org/projects/ark/>

<http://www.caida.org/>



# Ark Infrastructure

- **Archipelago** provides:
  - a powerful, globally **distributed measurement** infrastructure connected via the Internet to a central server at CAIDA
  - **resource coordination** using the Marinda tuple space
  - **scalable** system **management**
  - versatile and **efficient measurement** methods
  - **flexible** scheduling, data transfer, indexing, and archival

An environment for easy development and rapid prototyping of experiments.



# Data from Infrastructure

- **IPv4 topology** data
  - **10.1 TB** data served by **PREDICT**, data.caida.org
  - Sep 2007 to June 2012 (**58 months**)
    - **17 B traceroutes**; 1850+K cycles
  - Per month: ~**431M** traceroutes; ~**175 GB**/month
  - Key **input to**, e.g., **AS links** and **alias resolution**
  - Each **team** collects traces from **10.1 million** /24s
- **IPv6 topology** data
- Supporting software: mper, Marinda, MIDAR, kapar

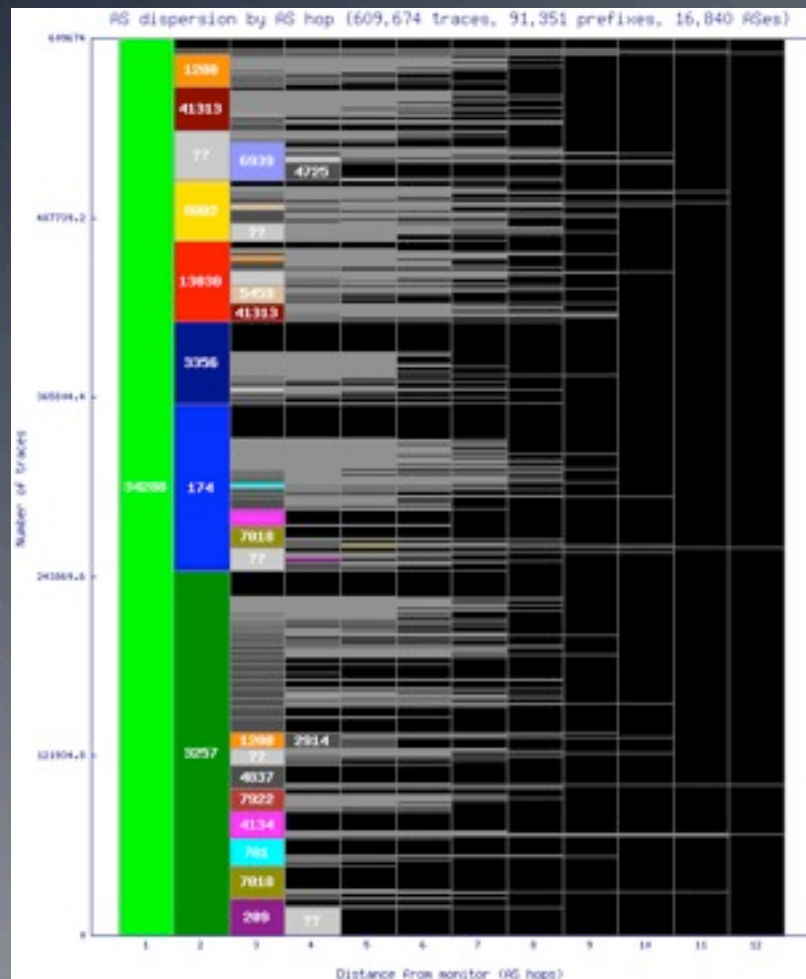


# Archipelago Monitor

- **Per-monitor analysis** of IPv4 topology data  
<http://www.caida.org/projects/ark/statistics/>
- Statistics aggregated across all monitors
  - **AS path length** distributions
  - Integrated **RTTs**
- Statistics from each monitor
  - **Median RTT** per **country** and **US state** (geographic map)
  - **AS hop dispersion** graphs (by AS hop and IP hop)
  - **IP hop dispersion** graphs
  - Distribution of **path lengths** (IP and AS)
  - **RTT distribution** (CCDF and quartiles vs hop distance)
  - **RTT** vs **geographic** distance



# AS Dispersion by AS Hop



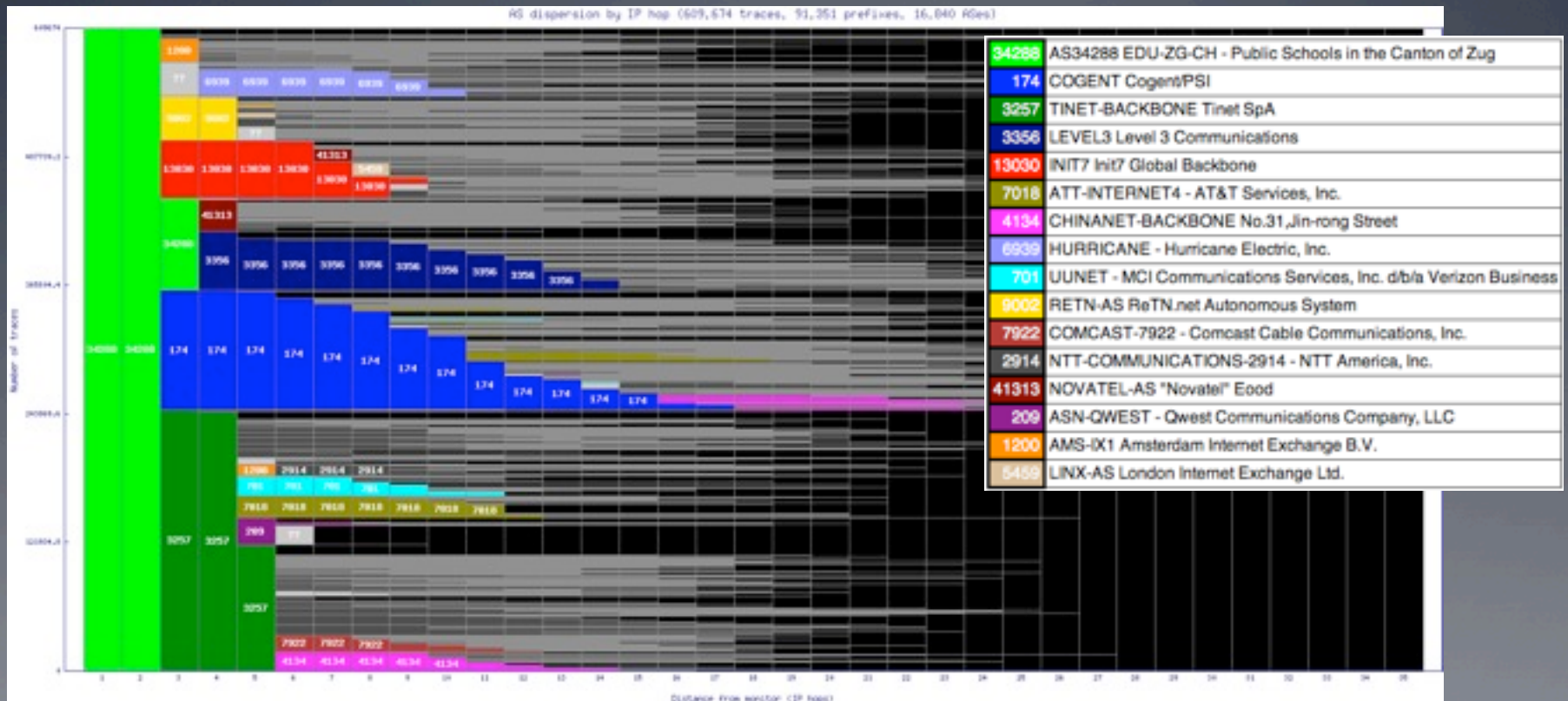
## Kantonsschule Zug (zrh2-ch)

34288	AS34288 EDU-ZG-CH - Public Schools in the Canton of Zug
3257	TINET-BACKBONE Tinet SpA
174	COGENT Cogent/PSI
3356	LEVEL3 Level 3 Communications
13030	INIT7 Init7 Global Backbone
41313	NOVATEL-AS "Novatel" Eood
9002	RETN-AS ReTN.net Autonomous System
7018	ATT-INTERNET4 - AT&T Services, Inc.
1200	AMS-IX1 Amsterdam Internet Exchange B.V.
4134	CHINANET-BACKBONE No.31,Jin-rong Street
209	ASN-QWEST - Qwest Communications Company, LLC
6939	HURRICANE - Hurricane Electric, Inc.
701	UUNET - MCI Communications Services, Inc. d/b/a Verizon Business
5459	LINX-AS London Internet Exchange Ltd.
7922	COMCAST-7922 - Comcast Cable Communications, Inc.
4837	CHINA169-BACKBONE CNCGROUP China169 Backbone
2914	NTT-COMMUNICATIONS-2914 - NTT America, Inc.
4725	ODN SOFTBANK TELECOM Corp.



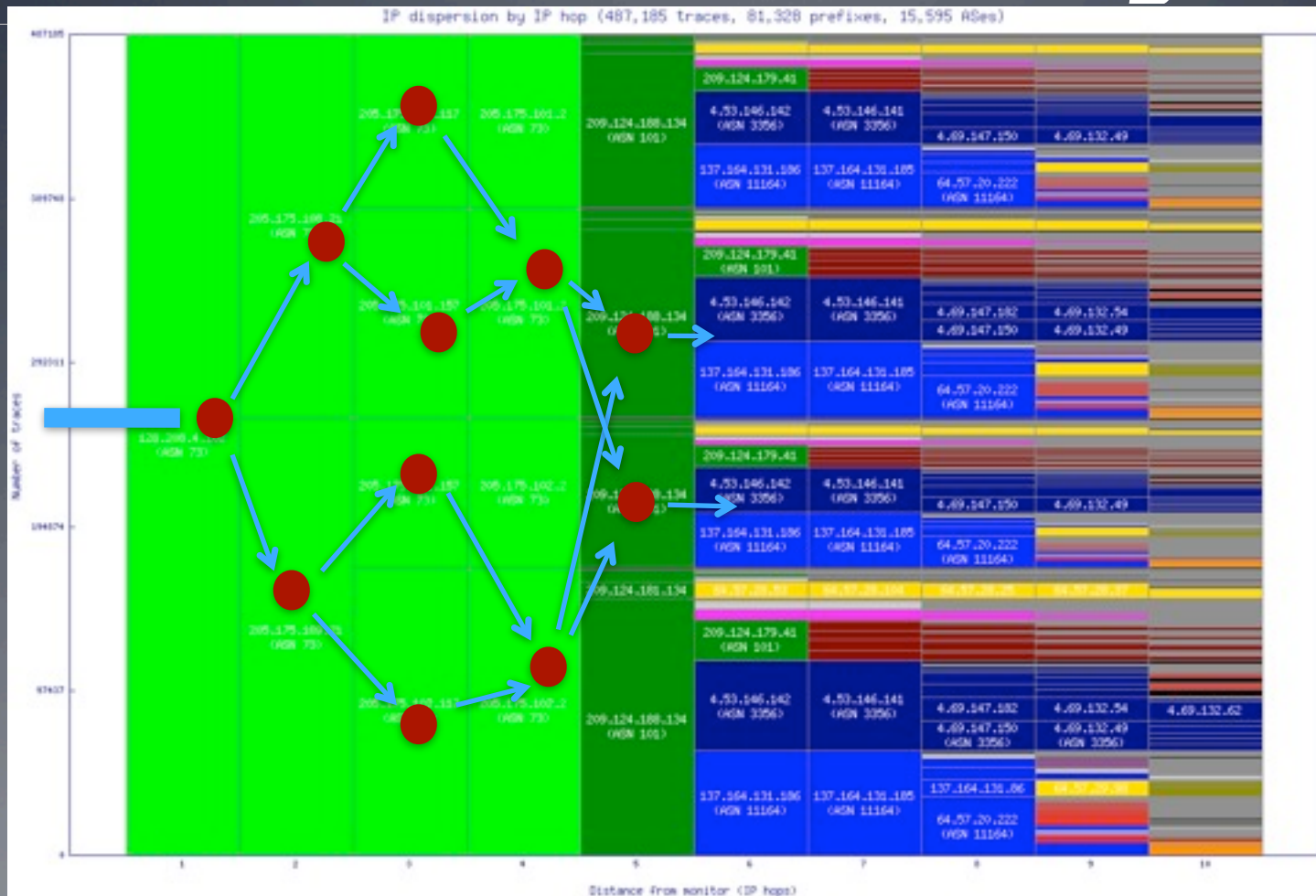
# AS Dispersion by IP Hop

Kantonsschule Zug (zrh2-ch)





# AS Dispersion by IP Hop: shows load balancing

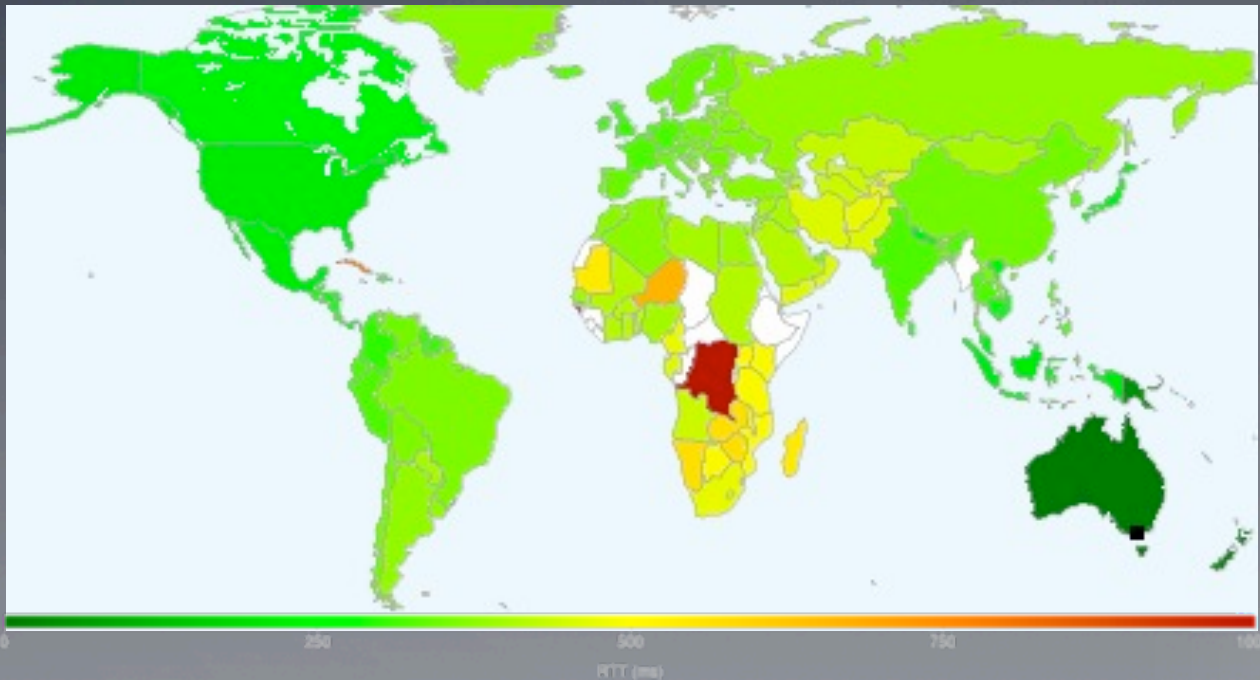




# Median RTT to Destination Countries



- RTT plotted by country
  - **Geolocate** destinations with **Netacuity** (MaxMind Lite for public release)
  - **Color** each country by **median RTT** destinations



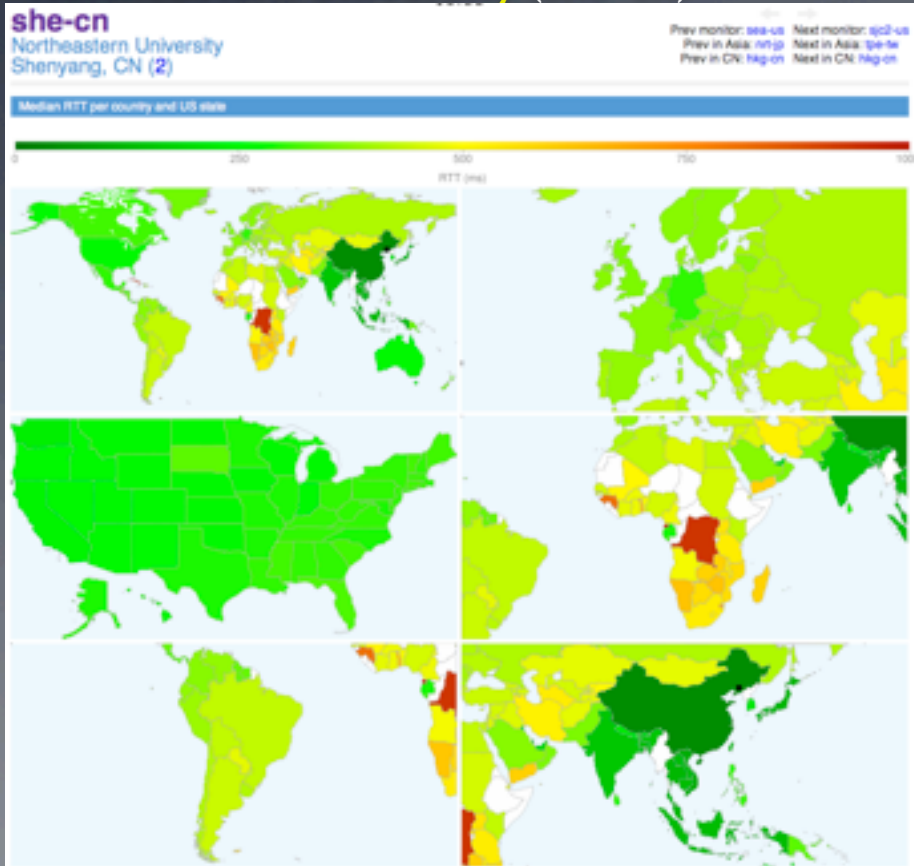
**University of Melbourne**  
(mel-au)



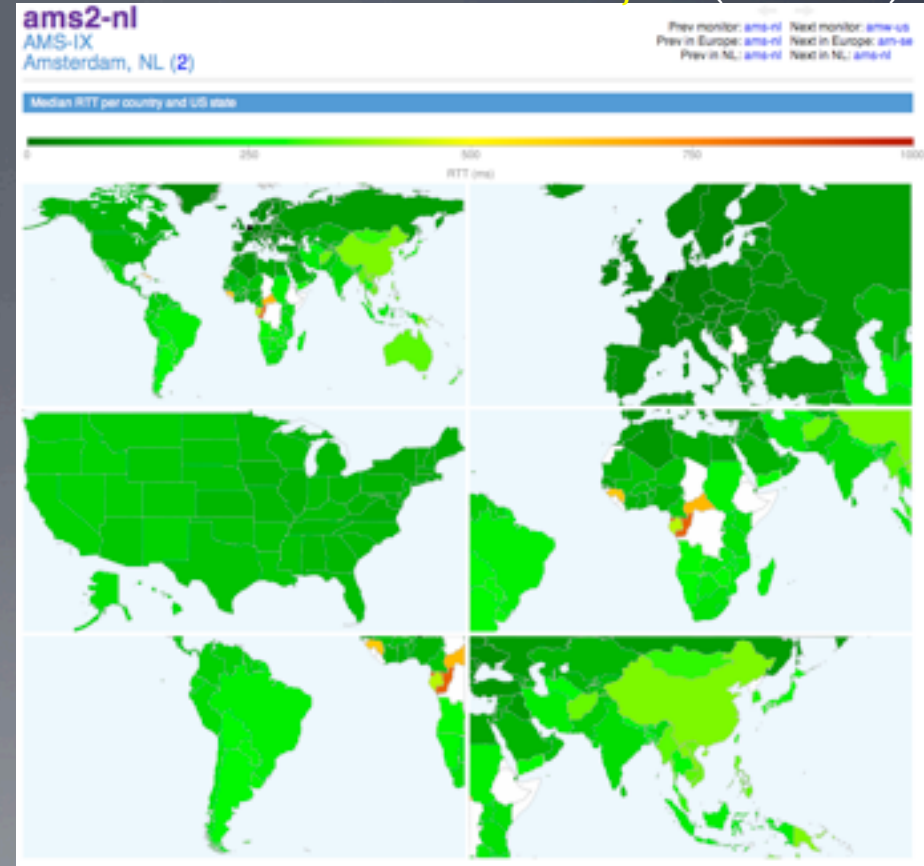
# Median RTT to Destination Countries



## Northeastern University (she-cn)



## AMS-IX Amsterdam, NL (ams2-nl)

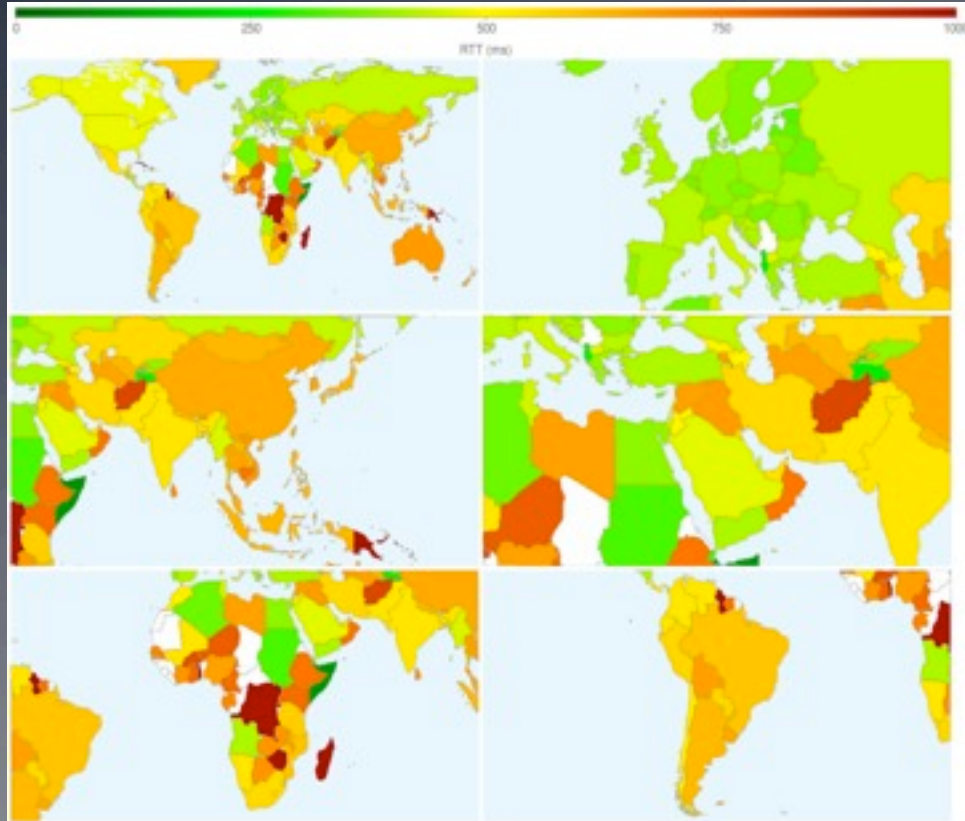




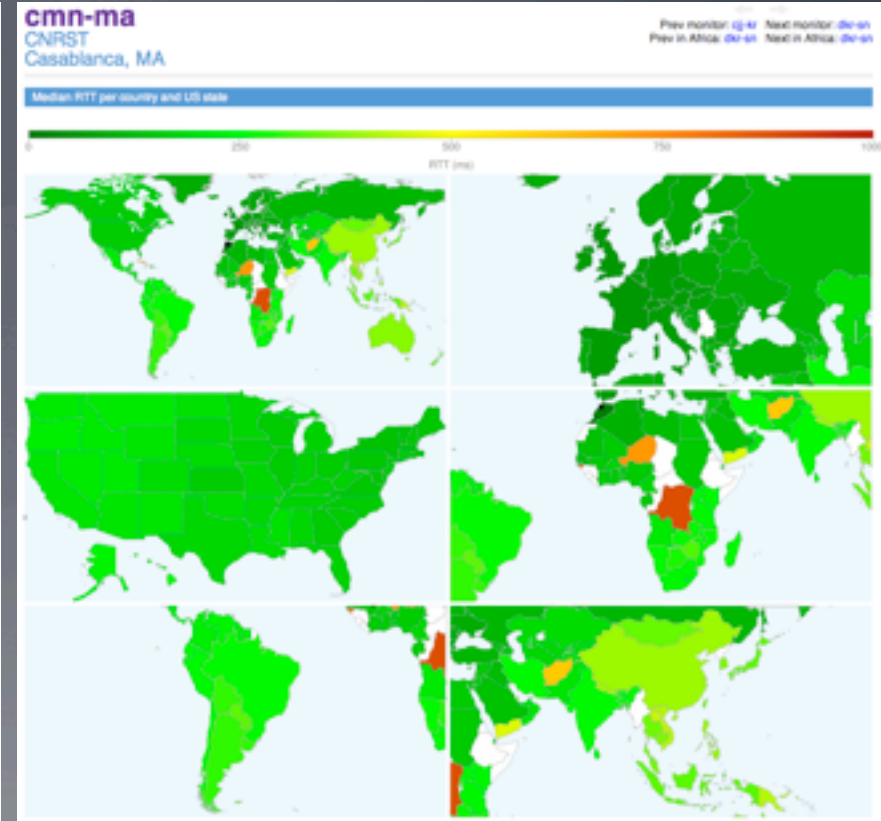
# Median RTT to Destination Countries



Sept 2010. Prior to new west coast Africa fiber



Oct 2011. After new fiber deployed

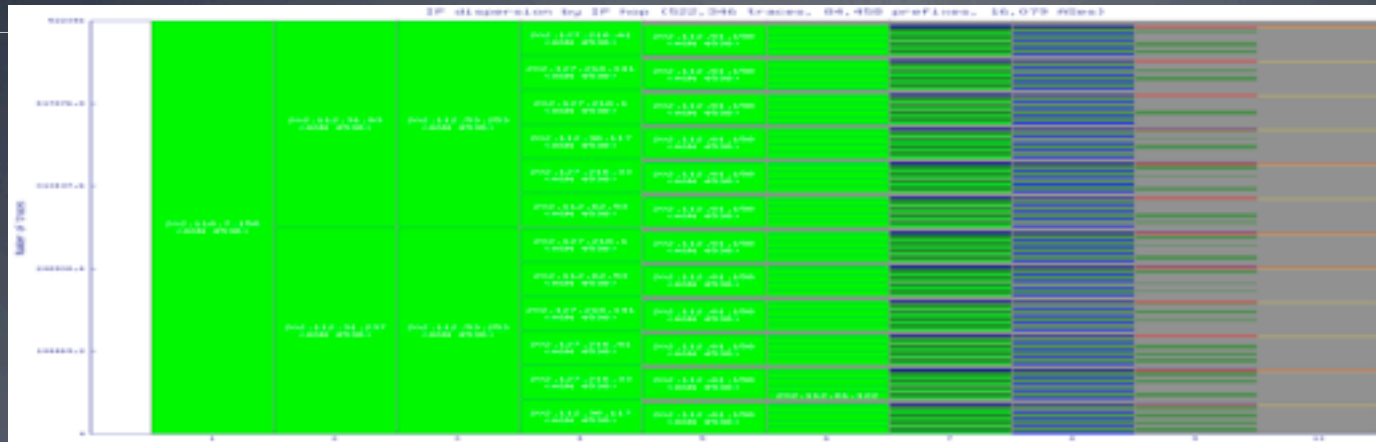


CNRST Casablanca, Morocco (cmn-ma)

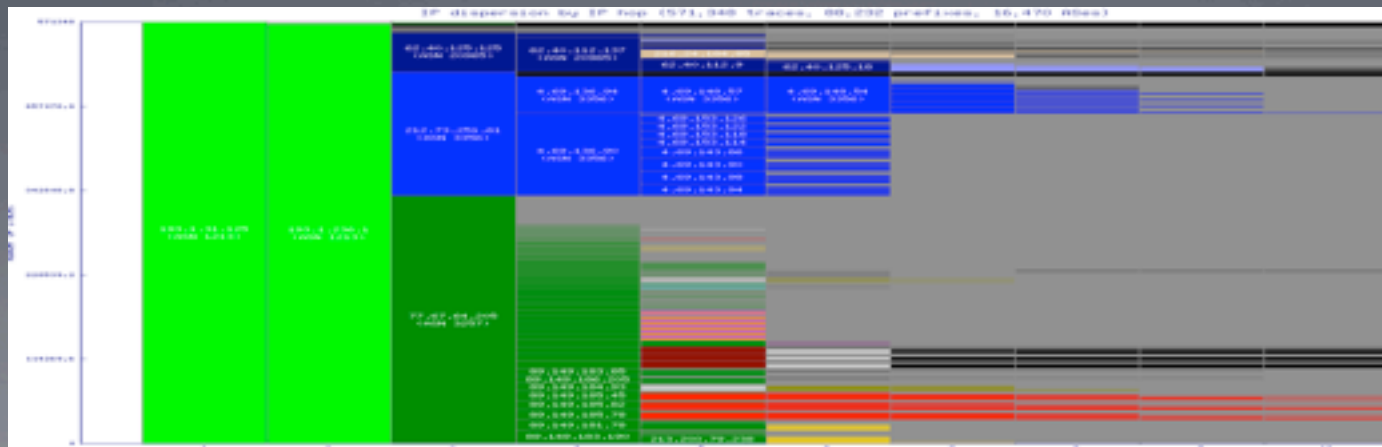
<http://www.caida.org/>



# IP Path Dispersion (by IP Hop)



**Chinese** monitor: shows IP load balancing over many hops.



**Irish** monitor: shows fewer IP hops to other ASes.



# Ark Topology Measurement

---

- Ark continuously gathers the **largest** set of **IPv4** and **IPv6 topology data** made available to academic researchers and government agencies.
- From Sep 2007 through June 2012, we have collected more than **17 Billion traces** (6.7 TB uncompressed, 2.1 TB compressed).



# Topology Measurement History

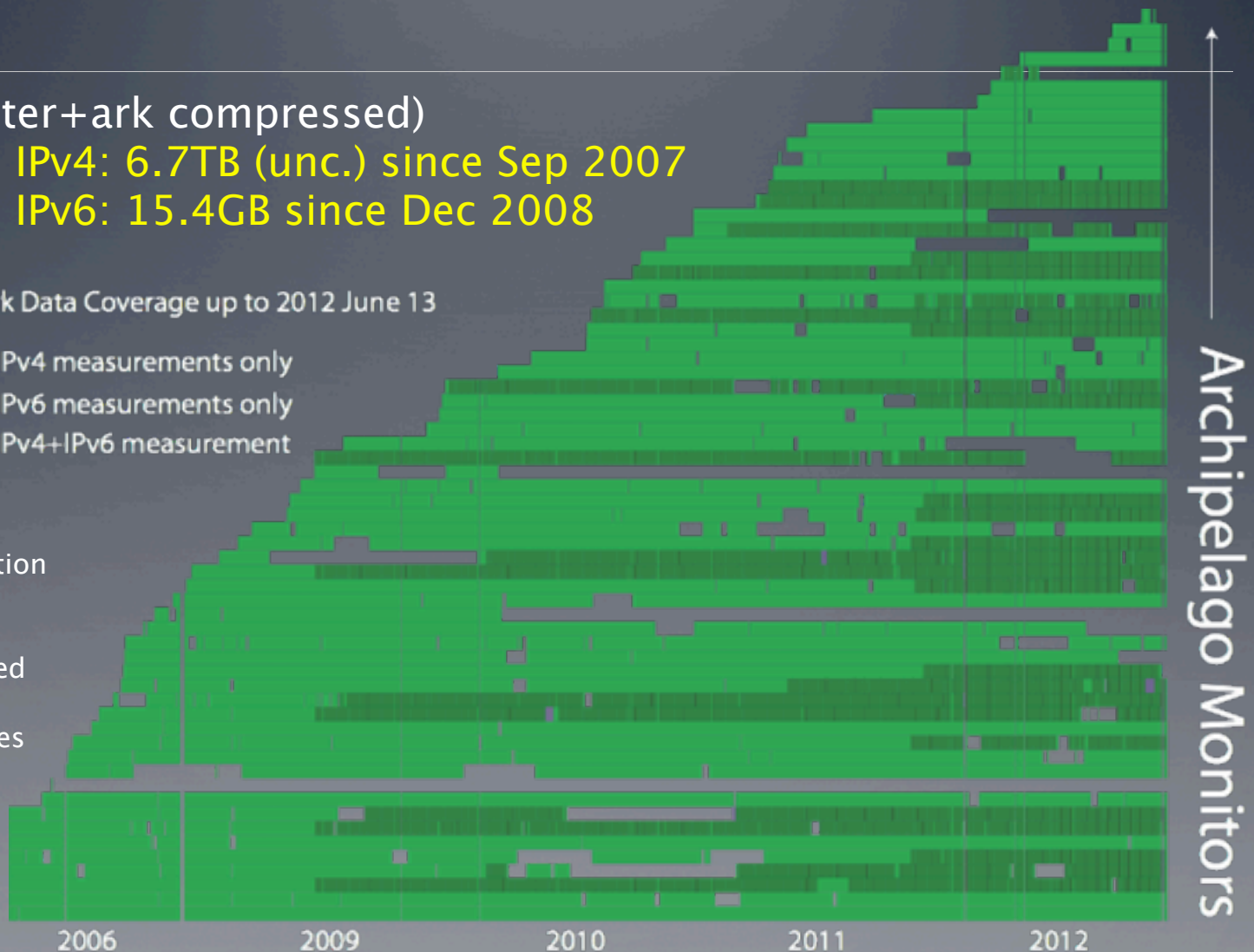
- 3.6 TB (skitter+ark compressed)
  - routed IPv4: 6.7TB (unc.) since Sep 2007
  - routed IPv6: 15.4GB since Dec 2008

Ark Data Coverage up to 2012 June 13

- IPv4 measurements only
- IPv6 measurements only
- IPv4+IPv6 measurement

Raw traces area a collection of IP paths.

For researchers interested in a single microscopic snapshot, CAIDA provides the ITDK



<http://www.caida.org/>



# Topology Datasets

---

1. **IPv4 Routed /24**: topology probes to each /24, continuously
2. **IPv4 Routed /24 DNS Names**: DNS annotations, also capture raw DNS query/response traffic
3. **IPv6 Topology**: topology probes to each routed IPv6 prefix
4. **Internet Topology Data Kit (ITDK)**: curated IPv4 data
5. **IPv4 Routed /24 AS Links**: AS adjacencies
6. **AS Relationships**: inferred AS business relationships

<http://www.caida.org/data/>



# IPv4 Routed /24 Topology

- **ongoing** large-scale topology measurements
- ICMP Paris **traceroute** to every routed /24 (10.1M)
  - ~60% of total **IPv4** space (per Aug 2012 Route Views)
  - probing rate = **100 probes per second**
- running **scamper** probing tool
- dynamically assign measurements to teams of monitors
  - **3 teams active**, 18–21 members/team
  - a cycle through every **routed /24** takes **2–3 days**
  - each /24 is probed once per cycle



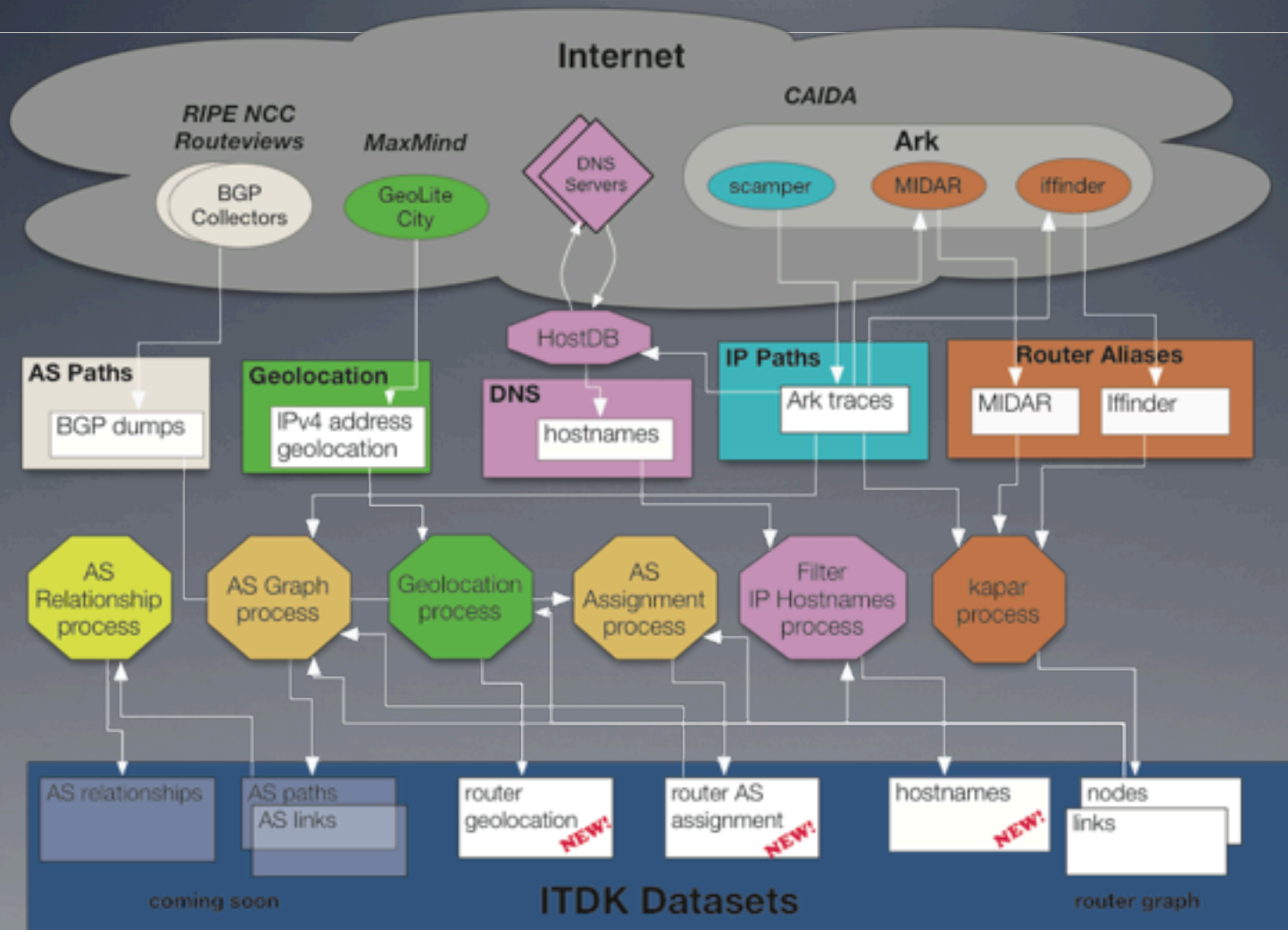
# IPv6 Topology

---

- **ongoing** large-scale topology measurements
- Ark monitors continuously probe BGP-announced prefixes **/48 or shorter**
  - 10,269 routed prefixes as of Sept 2012
- **Each monitor** probes a single random destination in **each prefix** using scamper



# Internet Topology Data Kit Process





# Internet Topology Data Kit

- Derived from **two weeks** of traceroute data probing **IPv4** addresses.
- Last ITDK just posted on [www.caida.org](http://www.caida.org) (July 2012)
- Two router-level **topologies**
  - 1) Optimized for accuracy: **MIDAR+iffinder**  
highest confidence aliases with low false positives.
  - 2) Optimized for completeness: **MIDAR+iffinder+kapar**  
more alias coverage, false positives (inflating routers)
- Data files: routers, links, router-to-AS mappings, router geolocations, DNS lookups of IP addresses



# Insights Enabled

- **Probing** technique performance comparison (w/ .NZ)  
M. Luckie, A. Dhamdhere, k. claffy, and D. Murrell, “Measured Impact of Crooked Traceroute”, ACM SIGCOMM (CCR), 2011.
- **Vulnerability** assessment: ingress filtering (w/ NPS)  
R. Beverly, A. Berger, Y. Hyun, and k. claffy, “Understanding the Efficacy of Deployed Internet Source Address Validation Filtering”, IMC 2009.
- Internet topology mapping: **IP alias resolution**
  - **Compare accuracy** of alias resolution techniques at Internet scale
  - **Enhancements**: (APAR++) [CCR 2010] , MIDAR [TON 2012]
  - Combine techniques (iffinder, kapar, ally, MIDAR) to **improve overall accuracy**
  - While others still saying it’s impossible [AMS2009]
  - Daunting challenge as always: remains **validation**



# Internet-scale IP Router Alias Resolution



- Goal: collapse observed **interfaces into routers**
- Earlier efforts at CAIDA: iffinder, kapar (APAR++)
- Most recent approach: **MIDAR** (inspired by RadarGun)
  - Two interfaces on same router respond in similar way
  - **IP ID** values in responses: **fingerprints** to find aliases
    - IP ID: 16-bit header field supporting frag&reassembly
    - Two interfaces on same router probed closely in time will return similar IP ID values: over time, similar time-series velocity.
- Architecture paper to appear in TON2012



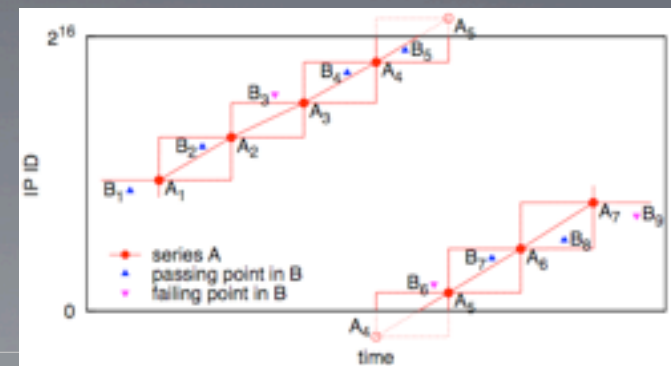
# MIDAR Approach



<http://www.caida.org/tools/measurement/midar/>

- Monotonic ID-based Alias Resolution (**MIDAR**) is our **extension** of the **RadarGun** approach:
  - Monotonic Bounds Test: for two addresses to be aliases, their combined IP ID time series must be monotonic
  - Sliding window for scalable probing
  - **4 probing methods**: TCP, UDP, ICMP, “indirect” (TTL expired)
  - **Multiple monitors**

IP ID over time



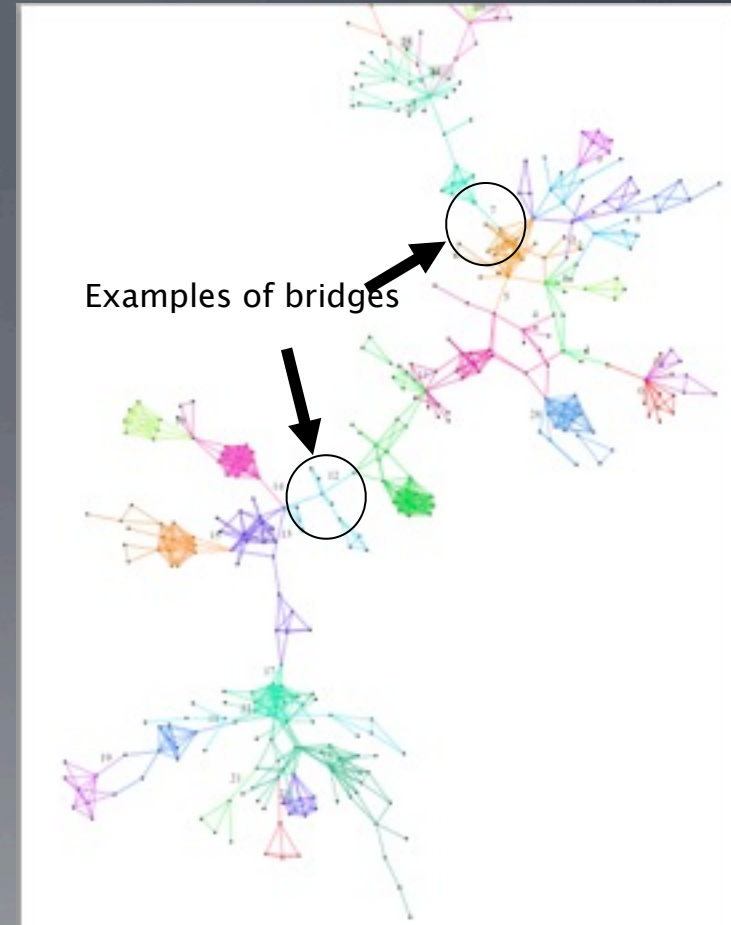
<http://www.caida.org/>



# MIDAR Elimination Stage

- Potential alias set found in Discovery stage
- Testing **pair-wise not scalable**, necessary, or always possible.
- Instead probe subsets [colors in graph], such that most addresses belong to only 1 subset
- **Probe a subset in parallel**
- Efficiently covers all pairs
- Reduces chance of rate limiting

IPs that are **potential router aliases**





# MIDAR Results

	2010-01	2010-04	2010-07	2011-04	2011-10
Input address	1.12 M	1.50 M	1.90 M		
Monotonic	0.99 M	1.20 M	1.44 M	2.32 M	2.19 M
address	486 G	724 G	1038 G	1.87 M	1.83 M
Possible pairs				1754 G	1676 G
Shared pairs after Discovery stage	1.63 M	4.00 M	5.49 M	6.83 M	7.00 M
Final Results					
•Shared pairs	0.433 M	1.36 M	1.67 M	2.49 M	2.68 M
•Routers	69 k	108 k	121 k	125 k	118 k
•Addresses on routers	189 k	383 k	426 k	413 k	403 k

- We have continually improved MIDAR over time:
  - **increasing** input **size** of the graph; and
  - **improving accuracy** and **effectiveness** of methods.



# Internet Topology Data Comparison



- **Topology** maps needed to analyze or model Internet structure
  - many studies use **inconsistent**, **incomplete**, or **undocumented** sources
  - undermines integrity of analysis results
  - objective: **enable informed selection** of topology datasets
- Approach: systematically **compare** best available **data**
  - characterizing topology at **three granularities**:
    - IP address (interface), router, Autonomous System (AS)
  - most comprehensive study: sources, metrics, methods, results
  - [http://www.caida.org/research/topology/topo\\_comparison/](http://www.caida.org/research/topology/topo_comparison/)



# AS Rank

- metric/indicator of **influence** over the global Internet interdomain routing system
- applications to: Internet science/modeling, infrastructure robustness/protection, public policy
- based on **inferred** economics of **AS business relationships** using data from public BGP tables
- orders by “**customer cone**”: number of IP prefixes advertised by each AS, by its customer ASes, by their customer ASes, and so on

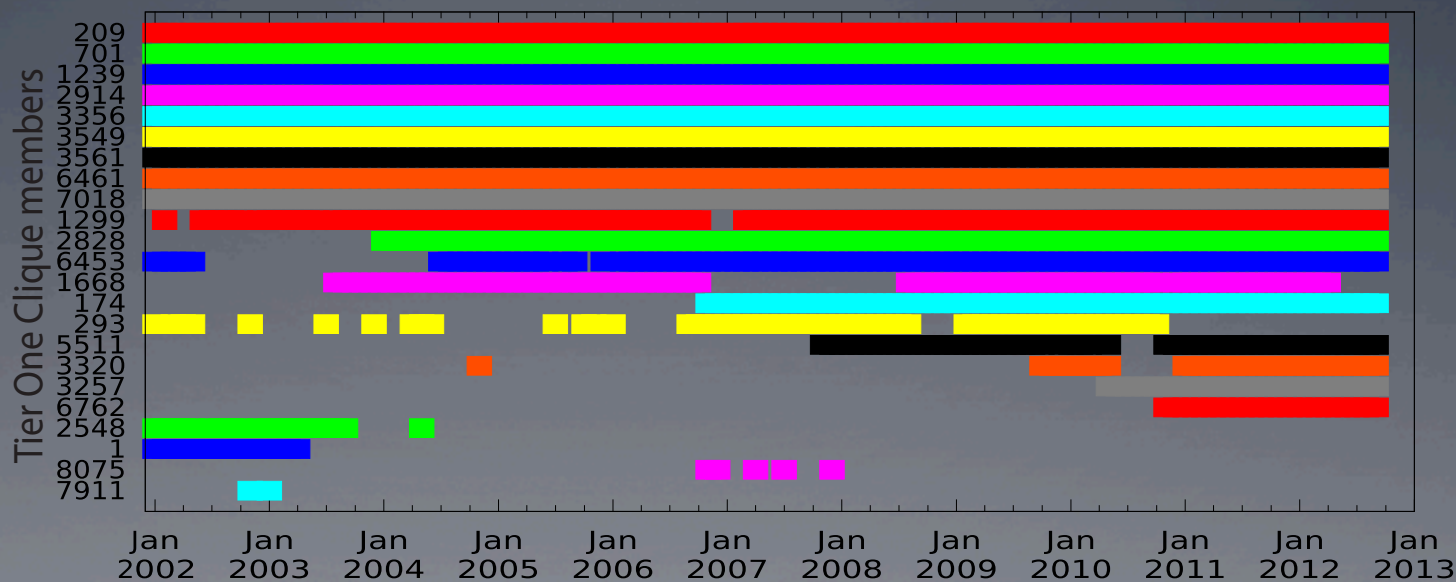
<http://as-rank.caida.org/>



# Top Tier AS clique

- Largest set of full meshed, clique, ASes from the top 40 ASes by degree

Top Tier Ases  
**clique members**  
over time





# AS Rank: screen shot



Top 10 ranked  
AS by customer cone

Level 3

AS Ranking

Org Ranking

Information for a single AS

Information for a single Org

Background

AS Ranking Help

Data Sources

Help

The top ASes ranked by customer cone size are displayed below.

For information about a specific AS, enter its AS name, its AS number, or the name of the Org of which the AS is a member.

Dataset: 2012.06.01

Look up an AS by number or name

Search

Table shows 10 of 41377 ASes, sorted by number of ASes in customer cone update view

AS rank	AS number	AS name	Org name	customer cone						AS degree
				Number of			Percentages of all			
				ASes	IPv4 Prefixes	IPv4 Addresses	ASes	IPv4 Prefixes	IPv4 Addresses	
1	3356	LEVEL3	Level 3 Communications, Inc.	29,037	291,344	1,456,474,500	70%	69%	56%	3318
2	3549	LVL-3549	Level 3 Communications, Inc.	25,105	260,300	928,688,621	60%	62%	36%	1499
3	1299	TELIA.NET	TeliaNet Global Network	21,887	217,829	933,429,605	52%	52%	36%	684
4	174	COGENT-174	Cogent Communications	21,206	215,777	849,203,950	51%	51%	33%	3539
5	3257	TINET-BACK...	Tinet Spa	18,211	206,207	796,599,260	44%	49%	31%	884
6	2914	NTT-COMMUN...	NTT America, Inc.	16,812	190,764	787,647,574	40%	45%	30%	791
7	701	UUNET	MCI WorldCom	14,781	188,837	879,888,016	35%	45%	34%	1812
8	1239	SPRINTLINK	U.S. Sprint	14,275	166,089	1,077,770,948	34%	39%	42%	969
9	6762	SEABONE-NET	Info-tel Communication S.r.l.	12,907	156,342	588,009,687	31%	37%	23%	264
10	6453	AS6453	TATA Communications formerly VSNL is Leading ISP	11,450	150,440	630,628,770	27%	36%	24%	549

data sources

geolocation	database	2012.06.25	netacuity
organization	whois	2012.04.01	AFRINIC, APNIC, ARIN, LACNIC, RIPE
topology	BGP	2012.06.01, 2012.06.02, 2012.06.03, 2012.06.04, 2012.06.05	ripe rrc00, rrc01, rrc03, rrc04, rrc05, rrc06, rrc07, rrc10, rrc11, rrc12, rrc13, rrc14, rrc15
			routeviews eqix, isc, linx, routeviews2, saoppaulo, sydney

<http://www.caida.org/>



# AS Rank (cont)

- Tabular views of inferred ISP info, rank, degree, customer cone size, customers, peers, and providers.

## ISP info



## Ranking

AS rank	AS	neighbor		type	projected peering: cone size (% of AS 1299's original cone size)		projected peering: cone size ratio	AS degree
		AS name	Org name		of neighbor AS	of AS 1299		
352	3301	TELIA NET-S...	TeliaNet Global Network	-- sibling	0.26%	99%	0.26	66
26818	31080	Q2-AS	TeliaNet Global Network	-- sibling	0.00%	100%	0.00	5
1	3356	LEVEL3	Level 3 Communications, Inc.	-- peer	132%	100%	75.38	3,318
2	3549	LVL3-3549	Level 3 Communications, Inc.	-- peer	114%	100%	87.18	1,499
4	174	COGENT-174	Cogent Communications	-- peer	96%	100%	96.89	3,539
5	3257	TINET-BACK...	Tinet Spa	-- peer	83%	100%	83.20	884
6	2914	NTT-COMMUN...	NTT America, Inc.	-- peer	76%	100%	76.81	791
7	701	UUNET	MCI WorldCom	-- peer	67%	100%	67.53	1,812
8	1239	SPRINTLINK	U.S. Sprint	-- peer	65%	100%	65.22	969
9	6762	SEABONE.NET	Info-tel Communication S.r.l.	-- peer	58%	100%	58.97	264

## Customers, providers, and peers

AS rank	AS	neighbor		type
		AS name	Org name	
352	3301	TELIA NET-S...	TeliaNet Global Network	-- sibling
26818	31080	Q2-AS	TeliaNet Global Network	-- sibling
1	3356	LEVEL3	Level 3 Communications, Inc.	-- peer
2	3549	LVL3-3549	Level 3 Communications, Inc.	-- peer
4	174	COGENT-174	Cogent Communications	-- peer
5	3257	TINET-BACK...	Tinet Spa	-- peer
6	2914	NTT-COMMUN...	NTT America, Inc.	-- peer
7	701	UUNET	MCI WorldCom	-- peer
8	1239	SPRINTLINK	U.S. Sprint	-- peer
9	6762	SEABONE.NET	Info-tel Communication S.r.l.	-- peer



# AS Rank Validation

- Interface to provide corrections to relationships

## relationship correction page

rank	neighbor AS	neighbor name	type	correction
3	<a href="#">3549</a>	Global Crossing Ltd.	↔ peer	provider ↕
4	<a href="#">6461</a>	Metromedia Fiber Net	↑ provider	↕
5	<a href="#">3257</a>	Tinet SpA	↑ provider	peer ↕
6	<a href="#">1239</a>	Sprint	↔ peer	↕
7	<a href="#">2914</a>	NTT America, Inc.	↔ peer	↕
8	<a href="#">174</a>	Cogent/PSI	↔ peer	↕
10	<a href="#">7018</a>	AT&T Services, Inc.	↔ peer	↕
11	<a href="#">3320</a>	Deutsche Telekom AG	↔ peer	↕
12	<a href="#">6453</a>	TATA Communications	↔ peer	↕
13	<a href="#">701</a>	MCI Communications S	↔ peer	↕

← corrections  
←

Disclaimer: We show these corrections as examples of the interface not as actual corrections received by TeliaNet Global Network.



# Geolocation Tools Comparison

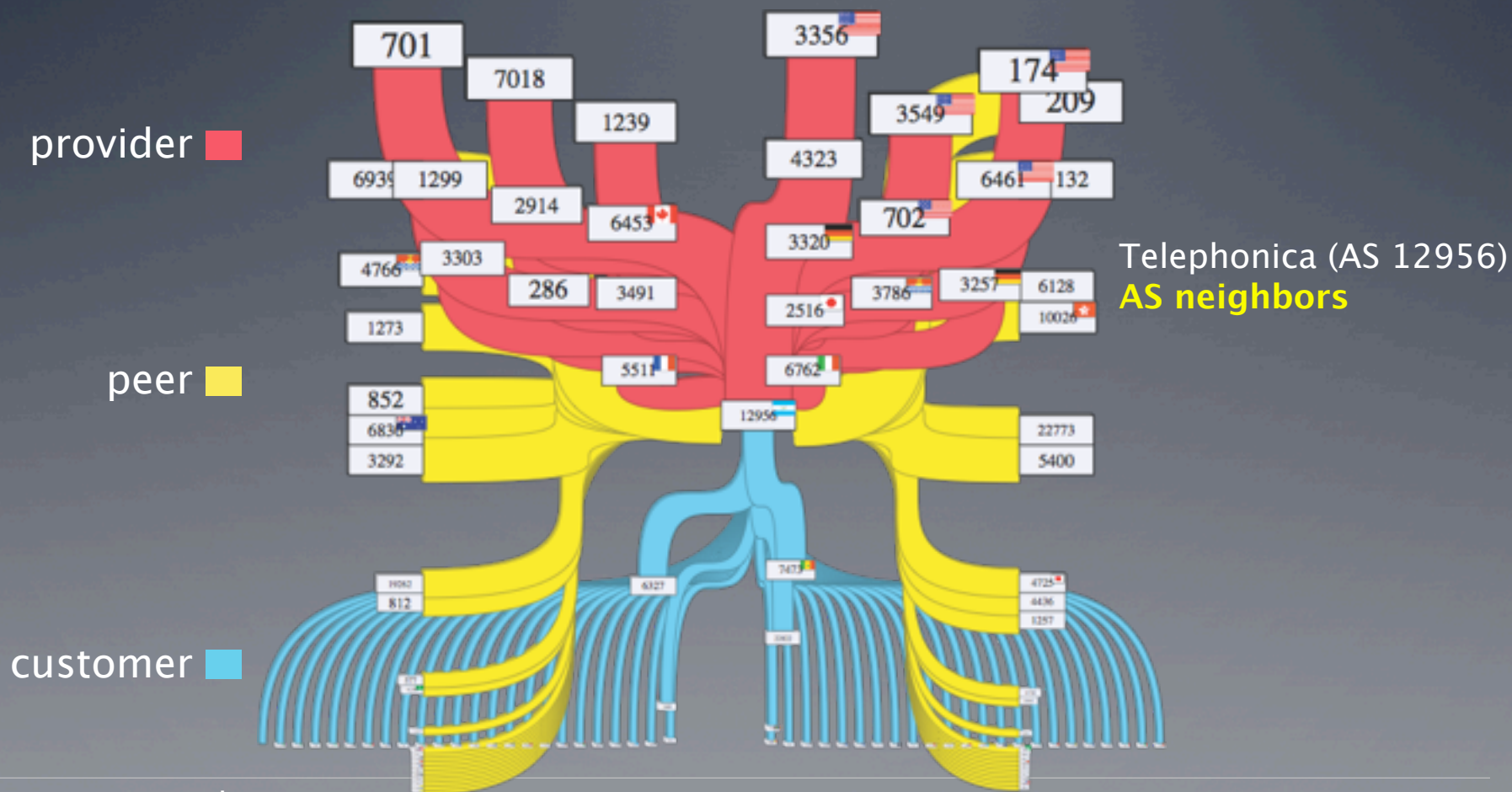
## (to support viz and analysis)

- Service evaluation criteria
  - What **geographic granularity** does it provide?
    - Continent, country, state/prefecture, city, zip code
  - What Internet **identifier granularity** does it support?
    - IP address, network prefix, Autonomous System (AS)
  - Does **accuracy** vary by region or type of network?
- We evaluated: Digital Envoy's Netacuity, MaxMind (Free and commercial), IP2Location, Ipligence, and HostIP.info. Quova and Akamai remain unwilling to participate.
- Results generally **agreed** on IP-address-to-**country** mappings
  - MaxMind Lite and GeoIP had the highest level of agreement (99.1%)
  - IPligence had the lowest level (94.3% )
  - Finer granularity harder to evaluate
  - **Netacuity** and **MaxMind GeoIP** performed “**best**” in our testing



# AS Rank Visualization

Graphical view of providers, peers, and customers

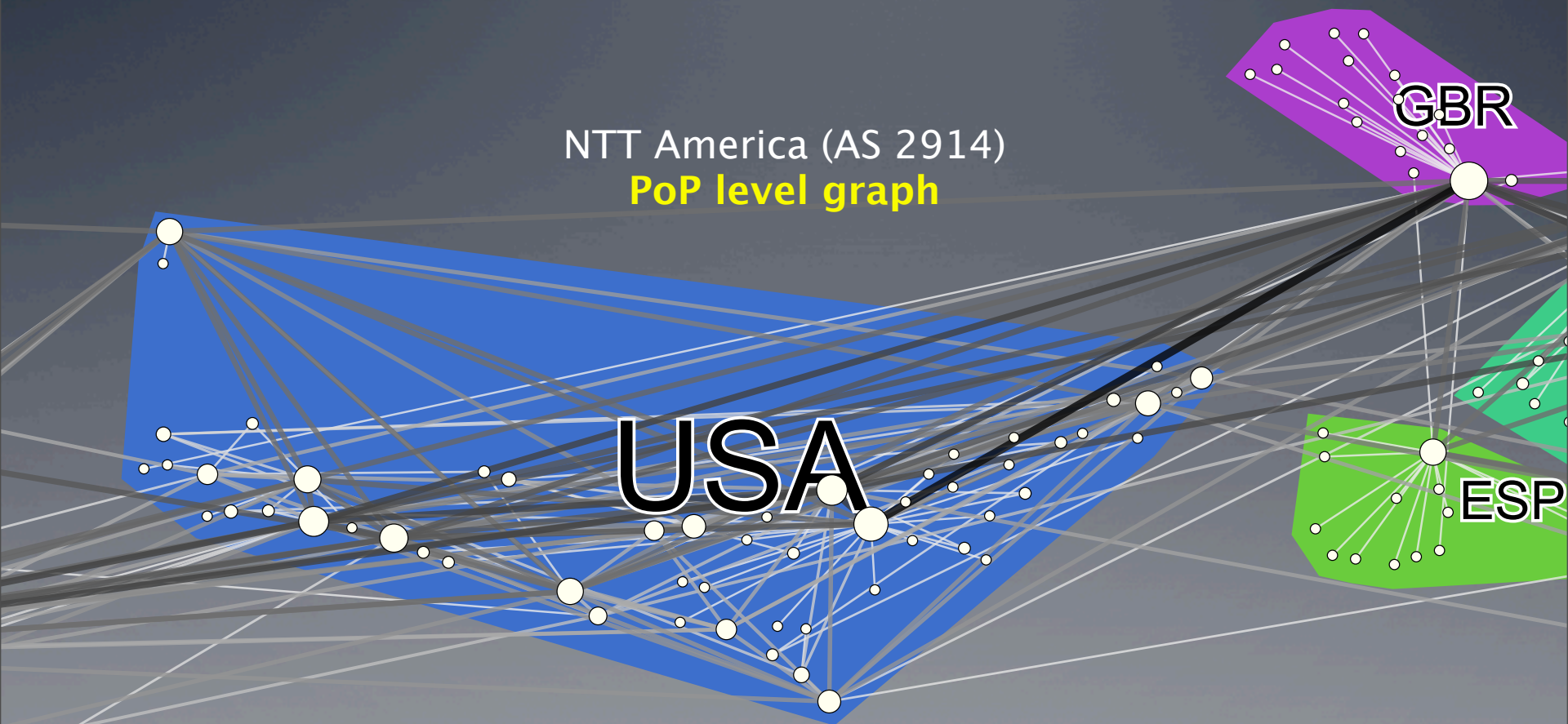




# Location Graph

Semi-geographic view of all routers for a given AS

NTT America (AS 2914)  
**PoP level graph**

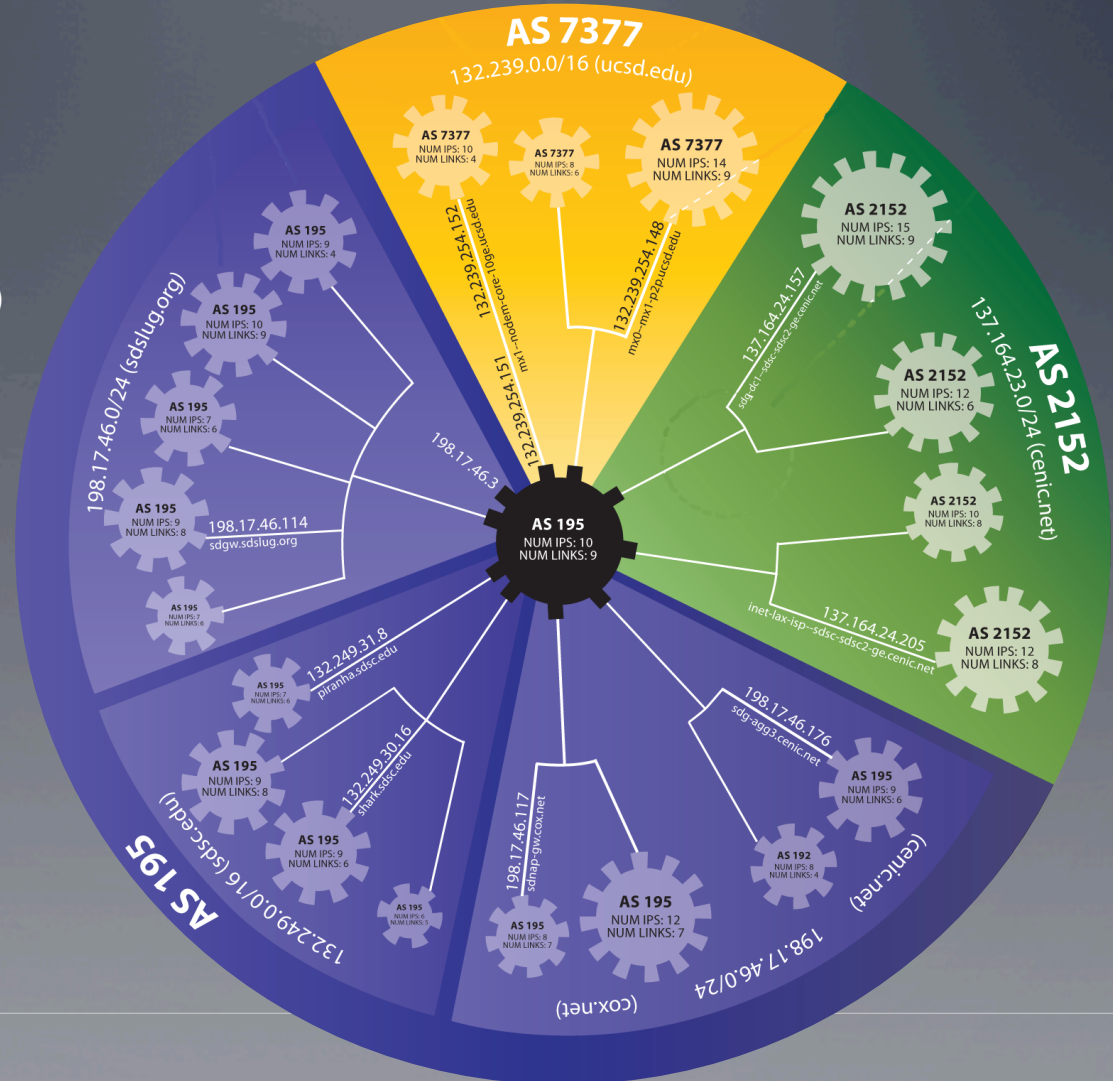




# Integrated Visualization of Topological Connectivity



UCSD router (prototype)  
**single router graph**





# Published Experiments Using Ark



- 1) “Traceroute Probe Method and Forward IP Path Inference”, IMC'08.
- 2) “Understanding the efficacy of deployed internet source address validation filtering”, IMC'09.
- 3) “Toward Topology Dualism: Improving the Accuracy of AS Annotations for Routers”, PAM 2010.
- 4) “The ISMA 2010 AIMS–2 Workshop on Active Internet Measurement Report”, ACM SIGCOMM Computer Communication Review (CCR), Sep 2010.
- 5) “Measured impact of crooked traceroute”, CCR, Jan 2011.
- 6) “The ISMA 2011 AIMS–3 Workshop on Active Internet Measurement Report”, ACM SIGCOMM Computer Communication Review (CCR), July 2011.



# Published Experiments Using Ark



- 7) “Geocompare: a comparison of public and commercial geolocation databases”, Network Mapping and Measurement Conference, May 2011.
- 8) “Twelve Years in the Evolution of the Internet Ecosystem”, IEEE/ACM Transactions on Networking, Sep 2011.
- 9) “Analysis of Country-wide Internet Outages Caused by Censorship”, IMC Nov 2011.
- 10) “Efficient Internet Topology Discovery Techniques”, Masters Thesis, U. Waikato, Alistair King, 2010.
- 11) “Sustaining the Internet with Hyperbolic Mapping”, Nature Communications, Oct 2010.
- 12) “Hyperbolic Geometry of Complex Networks”, Physical Review E, Oct 2010.

- \*\*Another 107 articles in Google scholar cite or use data from Ark as of 02 sept 2011.

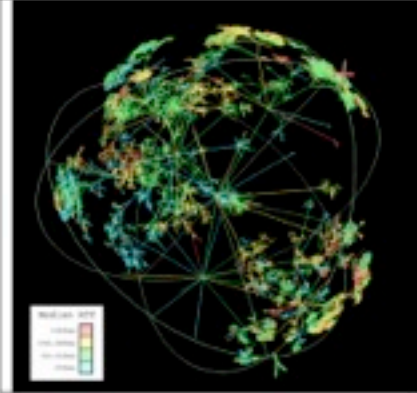


# Delivered Activities

- Deploy 1–2 monitors/month to measure IPv4 and IPv6 topology
- Continue to release and refine ITDK
- Publish alias resolution study and release three versions of code
- Annotated router-level graph visualization and database support
- Topology on demand measurements
- AIMS 2012 Workshop report → CCR
- AS Rank documentation, validation, new algorithms and interface
- Web-based interface to topo-on-demand service

<http://www.caida.org/funding/cybersecurity/>



<p>BAA Number: Cyber Security BAA 07-09  Title: Science and Technology of Internet Topology Mapping</p>	<p>Offeror Name: Kimberly Claffy  Date: 06/26/07</p>
<div data-bbox="150 212 569 601">  </div> <p>Walrus visualizations of round-trip time measurements made by CAIDA's macroscopic Internet topology monitor located in Herndon, VA, USA.</p>	<p>Internet Topology Mapping:</p> <ol style="list-style-type: none"> <li>1. Operational infrastructure to support continuous Internet topology mapping.</li> <li>2. Periodic active probing of 100% of BGP prefixes announced in publicly available routing tables.</li> <li>3. ISP relationship inference with accuracy up to 98%.</li> <li>4. Topologies at the router and AS granularity annotated with AS relationships, AS types, geolocations, latencies, etc.</li> <li>5. Empirically grounded quantified understanding of robustness, reliability, scalability and other characteristics of the Internet topology as critical infrastructure.</li> <li>6. Improved annotated topology maps will enhance modeling and monitoring capabilities to help identify threats and predict cascading impacts of damage scenarios.</li> <li>7. Visualization capabilities will provide powerful interface for use by DHS and other national security personnel.</li> </ol>
<p>Technical Approach:</p> <ol style="list-style-type: none"> <li>1. Expand current deployment of new distributed platform for continuous measurement of Internet topology, performance, state, and other characteristics.</li> <li>2. Use and improve IP alias resolution techniques to identify common routers to which IP interfaces belong.</li> <li>3. Further test and improve performance of software to convert IP technology data into router-level and AS-level graphs.</li> <li>4. Utilize CAIDA's AS relationship and AS taxonomy inference techniques and data infrastructure to annotate AS graphs with AS types and relationships.</li> <li>5. Apply and evaluate publicly available geolocation tools for use in annotating topologies with geographic data.</li> <li>6. Use CAIDA's or other visualization capabilities to depict structure and vulnerability-related characteristics of observed annotated Internet topologies.</li> </ol>	<p>Schedule, Deliverables, Contact Info:</p> <ol style="list-style-type: none"> <li>1. Current: new active measurement architecture: design complete; prototype implementation being tested.</li> <li>2. Year 1: <ol style="list-style-type: none"> <li>a. establish on-going IPv4 topology measurements using the new infrastructure;</li> <li>b. release software for calculation and exhaustive analysis of topology characteristics.</li> </ol> </li> <li>3. Year 2: <ol style="list-style-type: none"> <li>a. weekly updates of router topology with IP aliases resolved using best available techniques;</li> <li>b. weekly updates of AS/router graphs annotated with inferred AS relationships and types.</li> </ol> </li> <li>4. Year 3: <ol style="list-style-type: none"> <li>a. topology annotated with latencies and geolocations;</li> <li>b. annotated AS/router topology visualizations.</li> </ol> </li> <li>5. POC: Jennifer Ford, UCSD Contracts&amp;Grants, 9500 Gilman Dr, MC 0934, La Jolla, CA 92093-0934 Fax : (858) 534-0280</li> </ol>



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